SEMI-ANNUAL PROGRESS REPORT

ON

NASA RESEARCH GRANT NGR 45 - 001 - 011

"Analysis and Interpretation of Magnetic Field Measurements Between Earth and Mars Received from Mariner IV"

Covering the Period

June 1 through December 1, 1965

Brigham Young University
Provo, Utah

[redacted]

December 1965

I. INTRODUCTION

The research sponsored by this grant and made possible by the magnetometer data received from Mariner IV has been directed into the following areas:

1. The analysis of the near Mars magnetic field data.
2. A search for magnetic phenomena related to passage of the S/C into the region of the extended magnetic tails of the planets Mercury, Venus, Earth, and the moon.
3. Geomagnetic fluctuations as observed at several ground stations and their relation to magnetic conditions in space.
4. Analysis of the roll motion of the S/C as determined from the AGC signatures measured at the Woomera and Johannesburg tracking stations.
5. Calculation of the X and Y components of the S/C field.
6. Statistical nature of the interplanetary field.

The status of the work in each of these areas will be discussed both in relationship to what has been done and to what will be done. A portion of the work in item 6 above will be discussed here in relation to that of item 2. Other features of the interplanetary field have been reported elsewhere by Coleman, et al[1].

II. FIELD MEASUREMENT NEAR MARS

A preliminary analysis of the near Mars data has been reported by Smith, et al[2]. The primary conclusions of that paper were:

[redacted]

1. A scaling of the shock front boundary at earth to just within the trajectory results in an upper limit on the Martian magnetic moment of between 10^{-3} and 10^{-4} that of the earth.
2. There was a disturbance lasting for approximately three hours which started at $\sim$ 0123 GMT. This disturbance could be associated with either a weak Martian bow shock, or another of the many interplanetary events seen by the probe.

We are continuing to analyze the data related to the disturbance mentioned in (2) above in order to determine whether there is a high probability that the subject disturbance was more likely associated with a bow shock at Mars. In particular it may be possible to utilize the very interesting relationship between a characteristic change in the interplanetary field and certain disturbances observed here at earth that we have detected (see Section IV).

We at BYU feel that the timing of the disturbance in combination with its duraction is strongly suggestive of the possibility that indeed we did observe evidence of a Martian field. This is illustrated in Figure 1. The shock front boundary which appears to intersect the trajectory at the time as noted above is that which is for $M_M/M_E \sim 3 \times 10^{-4}$ corresponding to an aberation angle of $\sim 7^{o}$ as compared to a computed minimum value of $\sim 4^{o}$. The effect of an oblique interplanetary field as suggested by Walters[3] could easily make up this small difference.

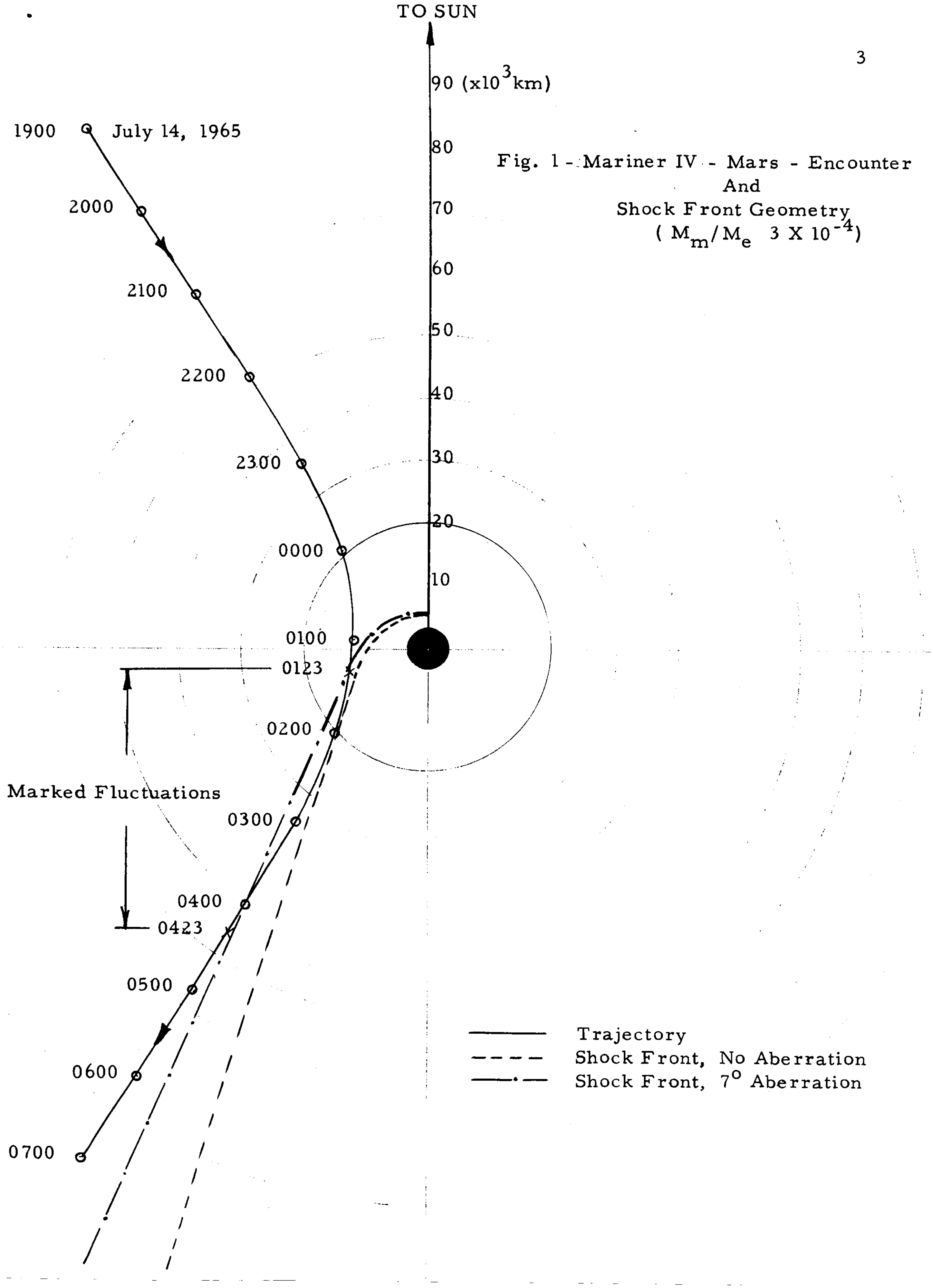


Fig. 1 - Mariner IV - Mars - Encounter And Shock Front Geometry (M_m/M_e 3 X 10^{-4})

III. PLANETARY MAGNETIC TAILS

The trajectory of the S/C and the motion of the several planets that lie within its orbit have afforded several opportunities to search for magnetic tails of the planets Mercury, Venus, Earth, and the moon. Table I lists pertinent geometric parameters related to the passage of the S/C into the region of the extended tails of the planetary bodies mentioned above. The parameter z is the distance to the S/C along the tail axis line and ρ the closest distance measured perpendicular to the z direction.

TABLE I

Planet	Day^T /Hour	α Degrees	z Planetary Radii	ρ Planetary Radii
Mercury	355/0400	7	40,400	5,200
	094/0200	7	55,000	6,500
	197/1900	7	162,000	1,000
Venus	234/0100	5	20,000	620
Moon	334/1300	4 1/2	203	23.4
Earth	032/2000	4 1/2	3,000	50

The time T is the time the S/C is at z and ρ and α is the aberation angle ($= \tan^{-1} \frac{V_p}{V_w}$) assuming an average solar wind velocity of 400 km /sec .

Proof of the existance of a magnetic tail resulting from the interaction of a planetary dipole moment with the solar wind has been faily well established as a result of the measurements of Ness[4] with the IMP I. It is not clear, however, how long such a tail should be, although there have been several estimates given of the expected shape and extent of the tail at great distances from the earth. Dessler[5] has suggested that the earth's magnetic tail is at least 100 R_e long, but is more likely to be $\sim$20 to 50 AU long. The radius of the tail should grow slowly from a value of $\sim 35R_e$ at 60 R_e to $\sim 70R_e$ at $\sim$2AU. Dungey[6] on the other hand suggests a tail length of $\sim 10^3 R_e$ and radius of $\sim 15R_e$. Piddington[7] has suggested an open tail model, but has not gone so far as to give dimensions of the tail except to estimate a cross-section diamter of $\sim 10R_e$.

The Moon. The first opportunity to pass behind a planetary body and search for possible magnetic effects associated with a magnetic tail occured on November 29, 1964 (Day 334) when the S/C went behind the moon (see figures 2 and 3). The S/C passed behind the earth during the earliest portion of the flight, but it was obviously too close to measure the characteristics of the extended terrestrial tail. (A preliminary analysis of the near earth data has been given elsewhere (1)). The aberation angle for the moon at this time was $\sim 4\ 1/2^{\circ}$ ($V_w \sim 400$ km/sec). The axis of the lunar tail is assumed to lie at this angle with respect to the sun moon line (see figure 3). As indicated in Table I,at the time of closest approach to the axis of the lunar tail, the S/C was $\sim 200 R_m$ along the axis and $\sim 23R_m$ below. The corresponding parameters for the passage of IMP I [4] into the lunar tail region were $z \sim 135R_m$, $\rho \sim 35R_m$ (December 1963) and $z \sim 210R_m$, $\rho \sim 15R_m$ (February 1964). Clearly the proximity of the Mariner IV to the axis of the lunar tail was fairly similar to the February 1964 pass. Ness has suggested that during the February pass, IMP I possibly detected the lunar wake, but that the characteristic features for this pass were different from those of the December pass. We are presently in the process of comparing the character of our data with that of Ness as well as pursuing other more critical types of studies to see if there is any statistically significant feature of this block of data that sets it apart from

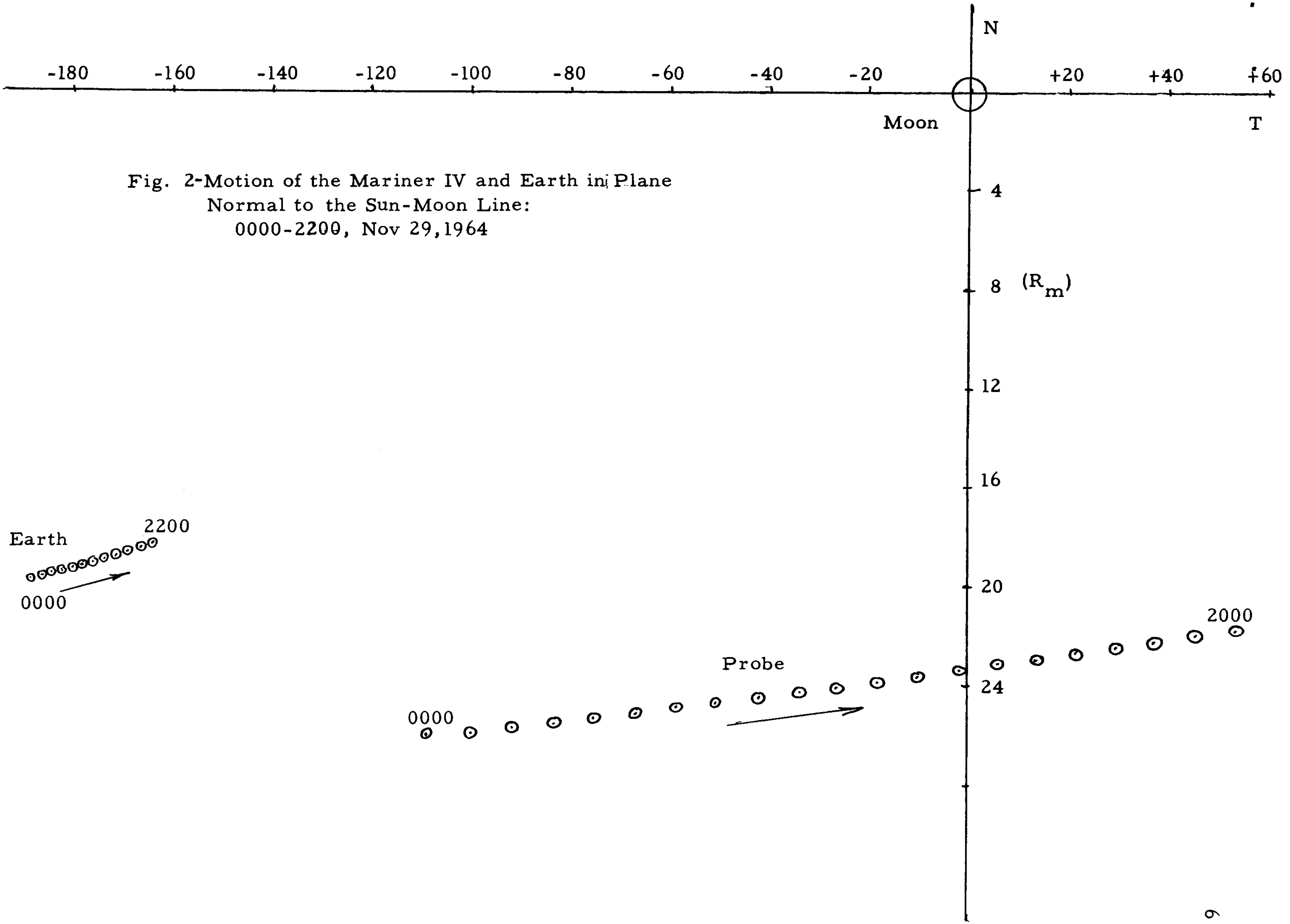


Fig. 2-Motion of the Mariner IV and Earth in Plane Normal to the Sun-Moon Line: 0000-2200, Nov 29,1964

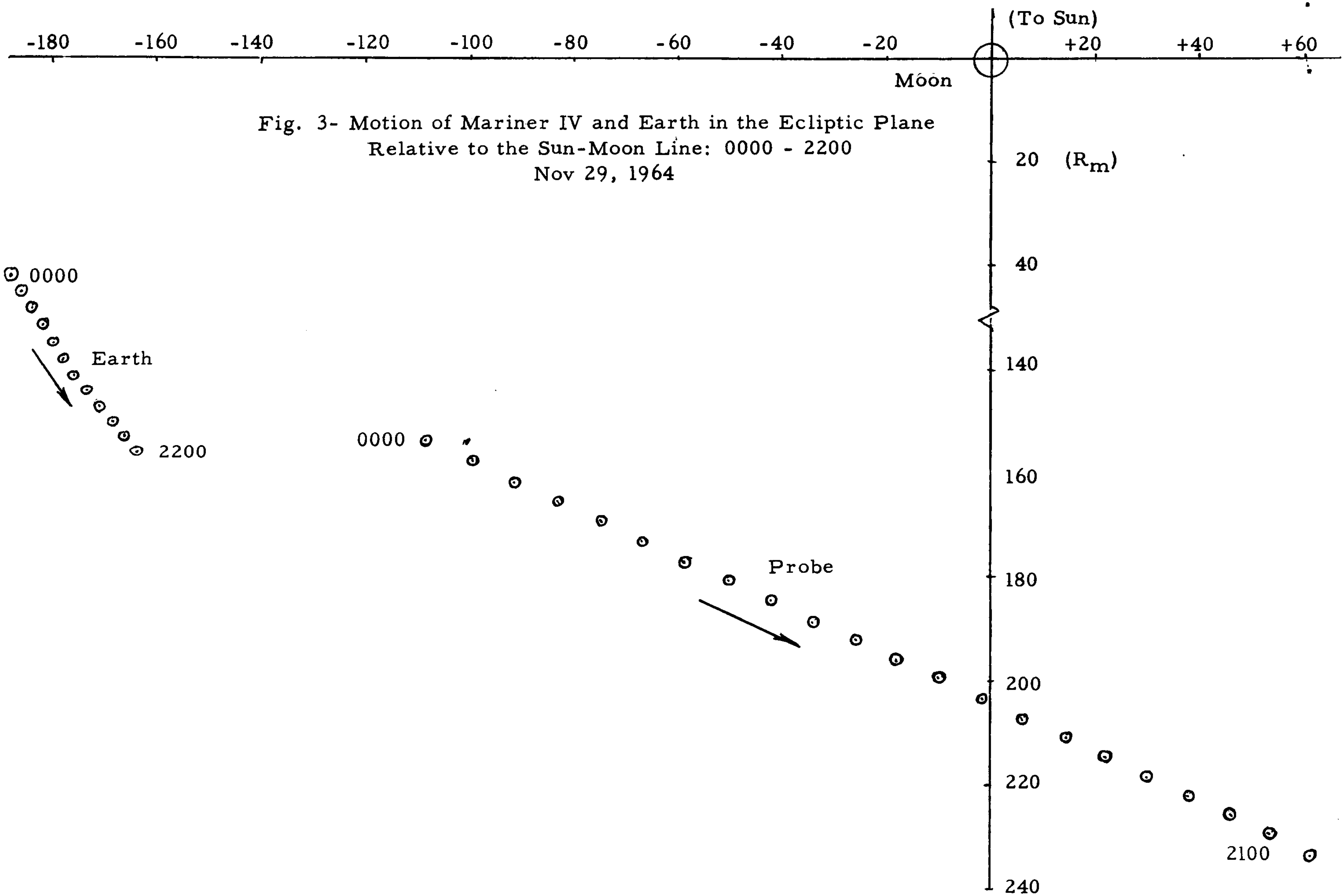


Fig. 3- Motion of Mariner IV and Earth in the Ecliptic Plane
Relative to the Sun-Moon Line: 0000 - 2200
Nov 29, 1964

data blocks taken from either side. There are disturbances in the field that exhibit a certain interesting symmetry with respect to the aberation line, but these disturbances could easily be interplanetary field disturbances like many others that have occurred.

The Earth. The relative motion of the earth and S/C placed the latter in the vicinity of the extension of the sun-earth line on January 28. Assuming a solar wind velocity of $\sim$400 kmpsec results in an aberation angle of $\sim 5^{\circ}$. The motion of the S/C in geocentric coordinates is shown in figure 4 and 5. Closest passage to the extended tail was on February 1. The pertinant z and ρ parameters are $\sim 3000 R_e$ and $50 R_e$ respectively.

The negative results of a preliminary analysis based on "quick look" (unedited) data has already been given[8]. Data in essentially final form has been received now covering the period from launch through Day 360 and Days 001 through 073, and we are presently applying a number of tests to the data to attempt to determine if there was anything statistically significant that would be attributed to passage of the S/C into the extended magnetic tail of the earth.

Auto-correlation functions of 27 day blocks of the data throughout the period of launch plus 2 days through day 150 have been computed. The magnetic data has also been cross correlated with solar 2700 mc/s flux and sunspot indices. Neither of these efforts has to date resulted in any suggestion that the data block centered around February 1 is statistically different from those outside this time. In fact the former work has shown fairly low auto-correlation indices suggesting that solar activity is fairly transient in character. We are presently cross-correlating the Mariner IV magnetic

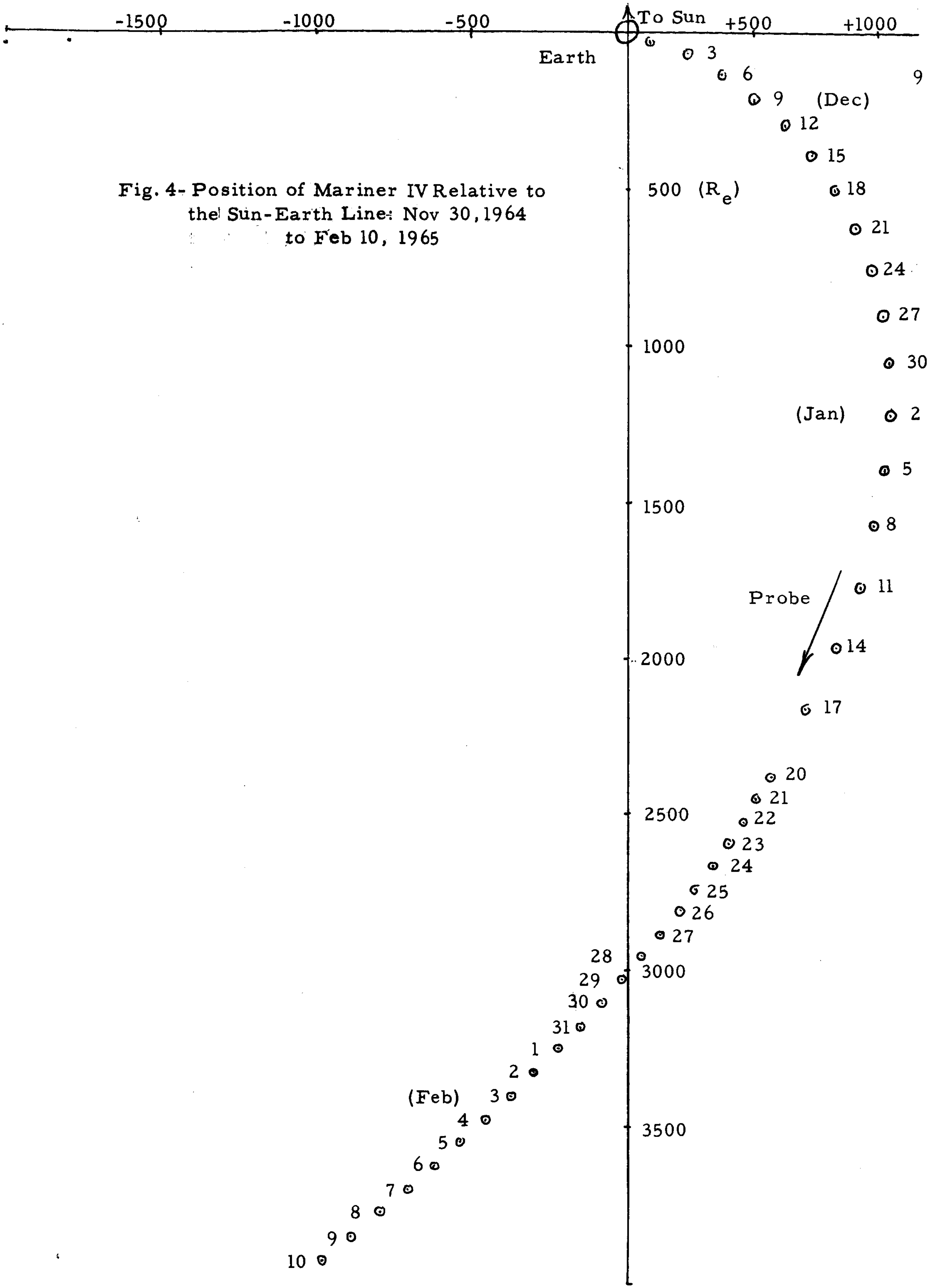
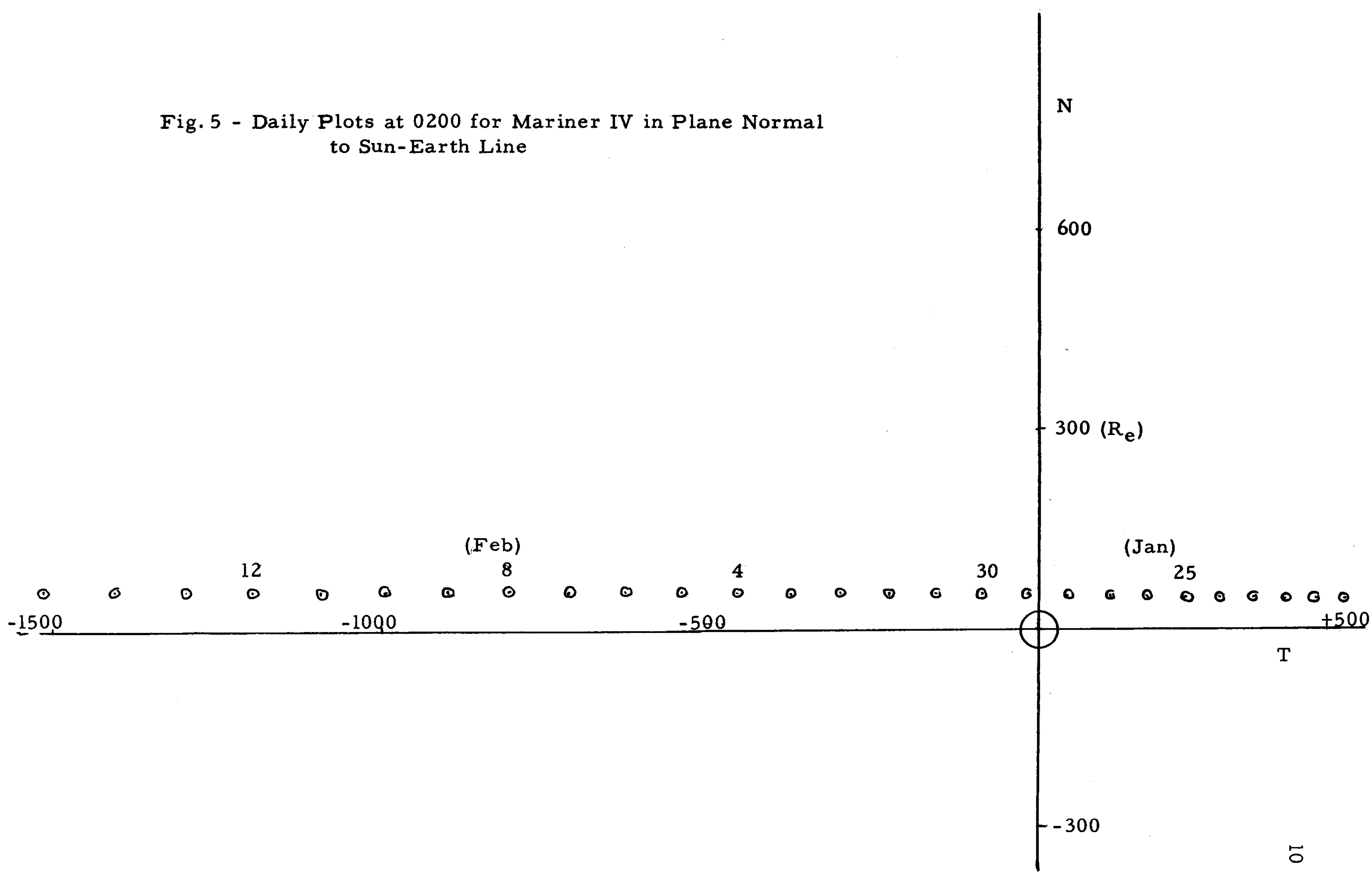


Fig. 4- Position of Mariner IV Relative to the Sun-Earth Line: Nov 30, 1964 to Feb 10, 1965

Fig. 5 - Daily Plots at 0200 for Mariner IV in Plane Normal to Sun-Earth Line



field and terrestrial ΣK_p data and relating interplanetary field changes at the S/C with other geomagnetic effects observed at earth and feel that this may prove fruitful insofar as establishing whether the February 1, etc., data block exhibits statistically significant differences from other data blocks. Other aspects of this latter effort are discussed in greater detail in Section IV of this report.

Other Planets. Of the several planetary inferior conjunctions involving Mercury and the S/C, none had ρ values within the predicted maximum value of $\sim 60\ R_m$. As noted in Table I, the S/C came closest to the extension of the tail axis shortly after the Mars encounter. The one conjunction of Venus resulted in a ρ value that was more than an order of magnetitude too large. Whereas it is clear from Table I that only for the moon and earth was there even a remote chance at having passed into the respective tail regions, the reasonably large interior angle of the chock fronts for all the planets suggest a possible program of searching for evidence of the latter, which we will be carrying out as soon as the final data is received.

IV. RESPONSE OF THE GEOMAGNETIC FIELD TO VARIATIONS IN THE INTERPLANETARY MAGNETIC FIELD

The unique trajectory of Mariner IV that kept it behind but very near the earth for several months has provided us with a long-term moniter of the magnetic character of the plasma streaming by and confining the geomagnetic field. At the present time we are deeply involved in a study of geomagnetic events both individually and statistically as they relate to magnetic changes observed at the probe.

A. The Data

1. The Magnetometer. "Quick Look" data has been available during the entire period covered by this report. However, there are serious gaps and discrepancies in this record. Accurate, edited data for the first few days of the flight was obtained in late September, and for the desired period (through February 28) in early November. We are now reworking our analysis with this new data to verify and extend the preliminary results outlined below.

2. Magnetograms. Magnetograms from a network of stations from Alert (82° N) to Byrd (80° S) have been analyzed for the first few days after launch. Results of this investigation prompted the decision to extend the analysis with only the near conjugate pair of College Alaska and Macquarie Island. Rapid-run magnetograms from these stations are being analyzed for the entire period of November 28, 1964, to March 1, 1965. Not all of the Macquarie records are available at the present time.

3. K_p and ΣK_p values were obtained for planetary scale events.

B. Relationship of the Interplanetary Field to Daily Geomagnetic Variability.

The study of the correlation of magnetic storms with solar events has a long history. At first, plasma streams were thought to traverse an empty region of space to the earth and initiate magnetic storms, but now we understand these jets of high energy plasma to be irregularities in a continuous solar wind. Already, satellite data has yielded a high statistical relationship between ΣK_p (daily planetary magnetic variability) and the velocity of the plasma reaching the magnetosphere(9). Other geophysical data such as energy spectra of particle streams, riometer records, neutron monitor values, etc., have prompted more recent descriptions of these solar disturbances such as the flare plasma cloud model proposed by Haurwitz, et al[10]*

Our study of the magnetic character of the plasma in relation to geomagnetic events has produced important additional information that must be assimilated in future models. In particular, the planetary index of magnetic variability in a day (ΣK_p) is related to the strength and orientation of the interplanetary magnetic field.

The results obtained from the Quick Look data for the period from November 29 to January 15 are presented in the upper part of Figure 6. This figure illustrates some of the additional analysis carried out at B. Y. U. The main points are:

(1) The total field strength is well correlated with ΣK_p. The completed data show a higher correlation than the ~.5 indicated in this preliminary figure. Furthermore, the high correlation continues for over 100 days.

(2) The cross correlation of ΣK_p with the field components indicates that there is a preferred direction of the interplanetary field when magnetic variability is observed on the earth. Furthermore, two days prior to the

* One aspect of this work dealing with the relationship of polarity (spiral in or out) of the interplanetary field and geomagnetic activity is to be submitted for publication shortly by Coleman et al. In this paper the work of Wilcox and Ness[11] has been clarified and the results obtain from the Mariner II, IMP and the Mariner IV are presented.

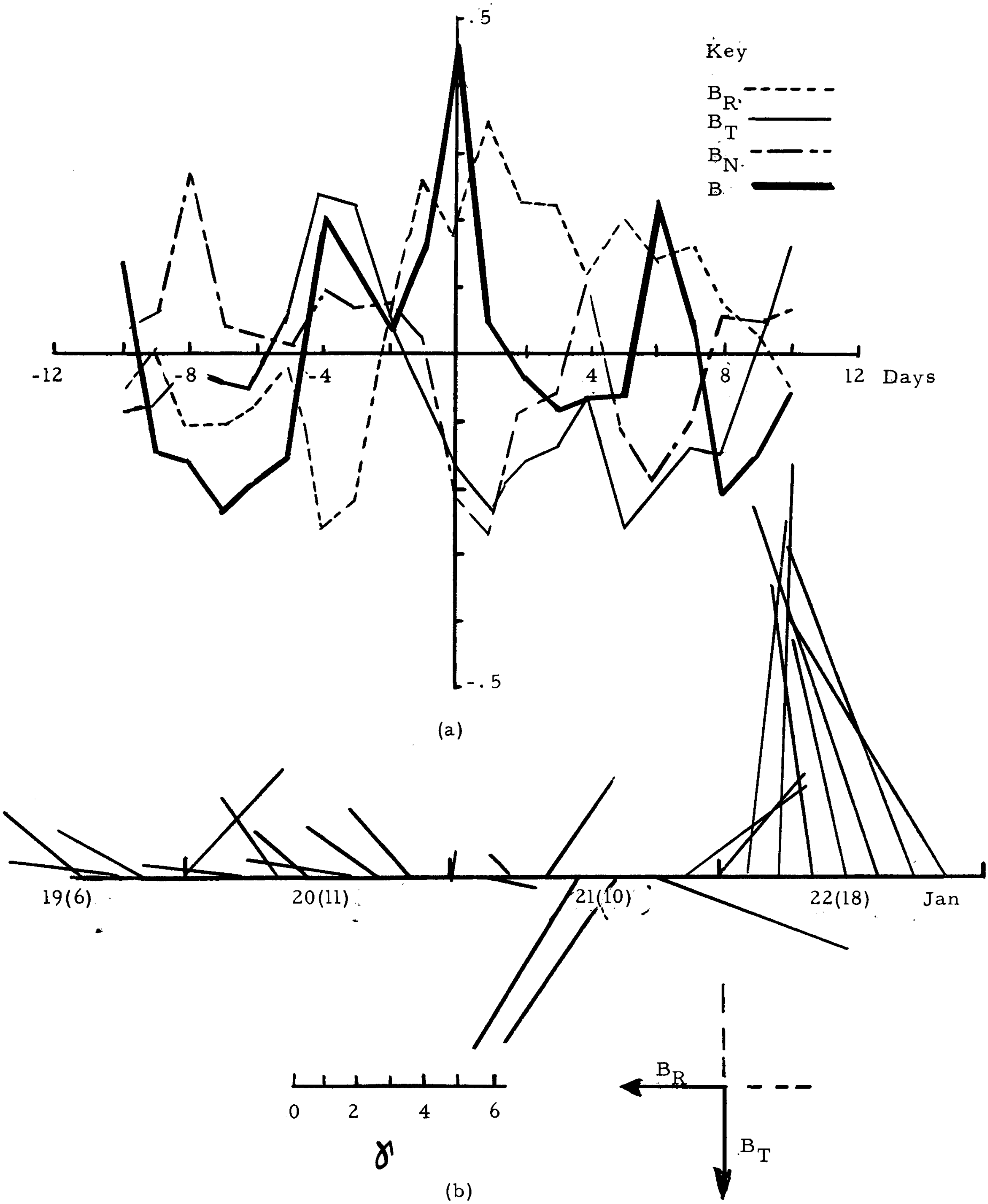


Fig. 6 (a) Cross Correlation of ΣK_p and 24 Hour Averages of B, B_R, B_N and B_T.
(b) Time Variation of the Interplanetary Magnetic Field Component in the Ecliptic Plane during late January. (Bracketed numbers are ΣK_p)

disturbance the interplanetary field has a minimum value and likely reverses its direction. The polarity studies mentioned above have suggested a relation between specific storms and interplanetary field reversals. This study, however, will give statistical credence to the idea and furthermore, it will show the three dimensional nature of the reversal.

A characteristic example is shown in the lower part of figure 6. The three hour means of B_R and B_T (field components in the ecliptic plane) are shown for several days in late January 1965. All of the features of the statistical description above are evident in this single event although the time scale is compressed. The changes in the tangetial component during this event are of great significance.

Our completed study will yield a quantitative model of large scale interplanetary magnetic events that result in planet wide geomagnetic variability.

C. Interplanetary Magnetic Events that cause Geomagnetic Disturbances

Our study has shown that the response of the earth field to interplanetary events is not restricted to the large scale statistical results presented above. In fact, it is possible to relate individual events seen at the probe with a wide assortment of disturbances at high altitude observing stations. The magnitude and duration of these correlated events varies from a few gamma and a few minutes to hundreds of gamma and days.

At the present time we are studying each event seen at the probe and at the earth during the period from November 28 to March 1. An important aspect of this problem is the lag time between events at the two points in space. After some time it became apparent that the rotational effect on lag time was inconsequential during the first few months and only the greater radial distance of the probe needed to be considered. Although there is some dispersion due to the different velocities of plasma events, it is possible to relate events for several months with considerable confidence.

To illustrate this part of the study we have presented in figure 7 both the rapid run magnetogram from College Alaska and the angular orientation of the interplanetary magnetic field in the plane normal to the sun probe line. The following points are of interest here:

(1) The probe saw an oscillation in the interplanetary field on December 3, 1964 centered at about 1150 V. T. The first abrupt change in direction of the field occurred just 15 minutes after a similar disturbance was seen at the earth.

(2) The total disturbance seen at the probe lasted less than forty minutes and the period of the primary oscillation was of the order of 10 minutes.

(3) The interplanetary field strength during the disturbance was low, ranging between 4 1/2 and 7γ

(4) The geomagnetic disturbance was confined to high latitudes. Furthermore, only certain sectors in the auroral zone recorded the vent.

The careful analysis of these events will lead to a better understanding of solar initiated events and perhaps to the identification of instabilities in the interplanetary plasma. The event presented in figure 8 has many of the characteristics of the "hose" type instability described by Parker[12].

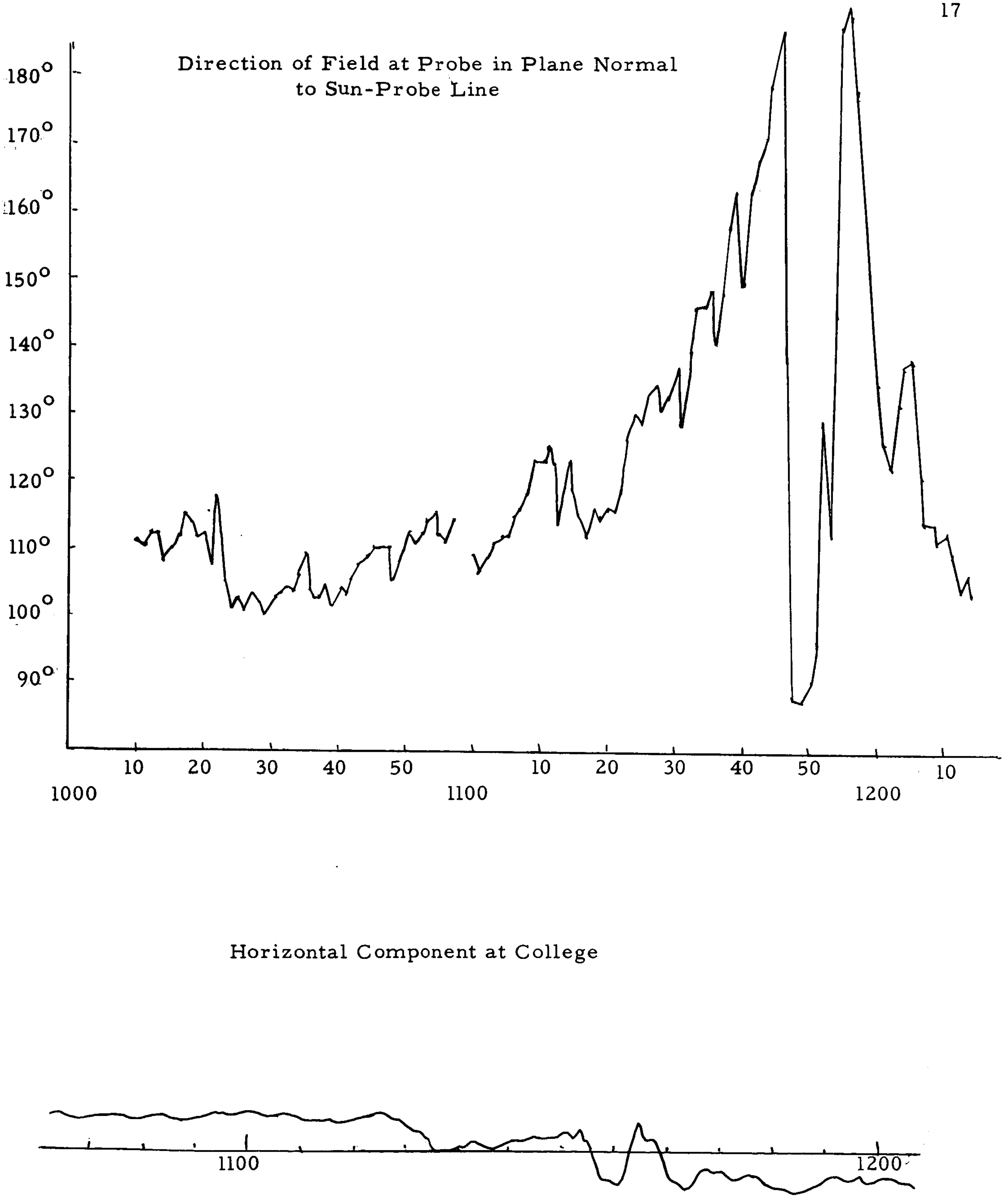


Fig. 7 - Comparison of Interplanetary and Terrestrial Field Changes; Dec 2, 1964

D. Geomagnetic Micropulsations and the Interplanetary Field

Sinusoidal disturbances in the earth's magnetic field have commonly been attributed to hydromagnetic waves propagating either transverse to or along the field lines of the earth. Patel[13] has presented evidence for such waves observed in the magnetosphere. We are studying pulsations with periods between 1.5 and 10 minutes. Pulsations of this range are pronounced only in auroral regions. Our study has produced information that will lead to a quantitative relationship between the interplanetary magnetic field and the period of the hydromagnetic waves initiated near the magnetopause. Furthermore, dependency on local time for excitation of such waves will yield certain information about the configuration of the geomagnetic tail.

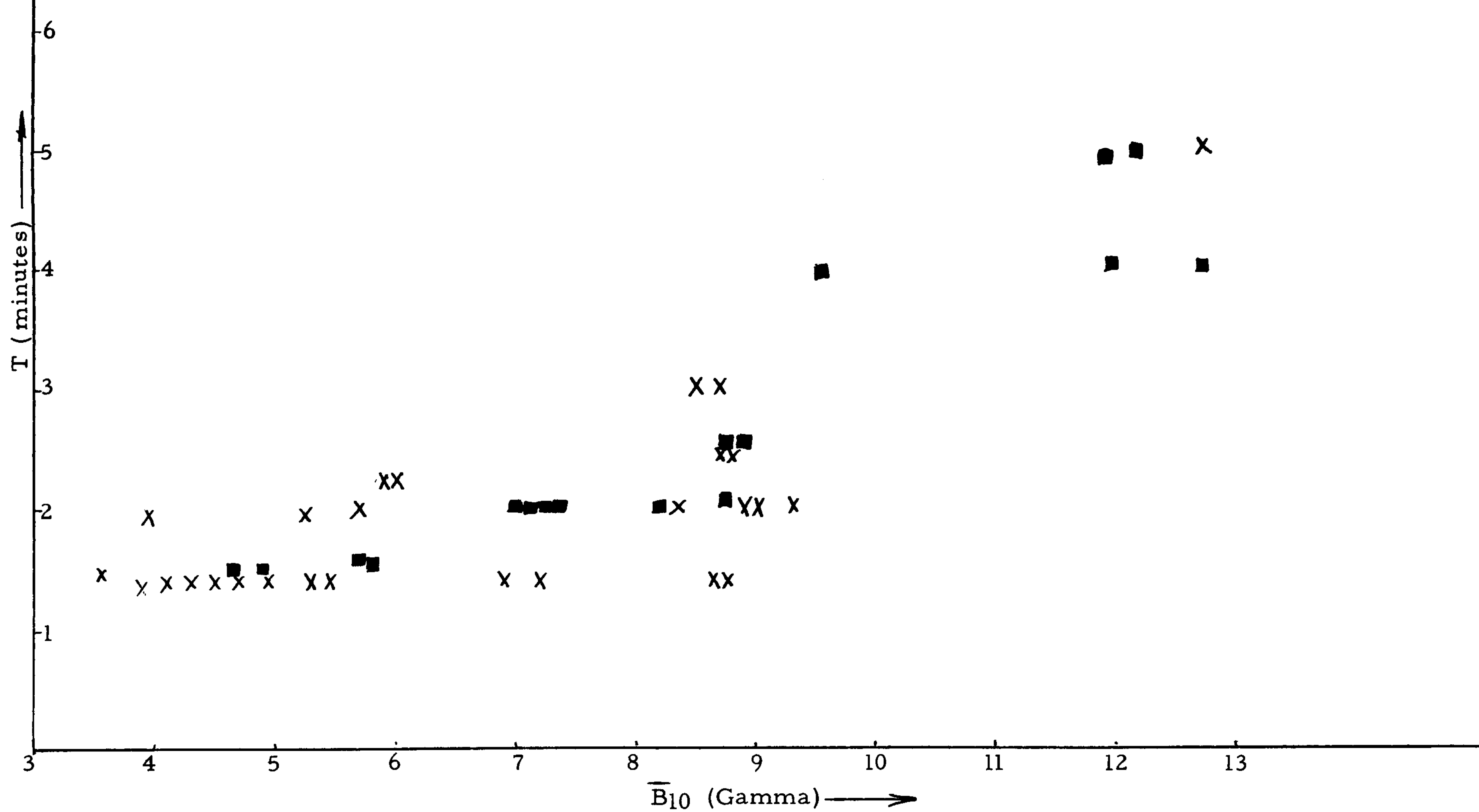
Figure 8 suggests a surprising relationship between period of earth pulsation and strength of the interplanetary field. With extended data, we have now verified that the long period waves are seen when the interplanetary field is strong.

We are working on a geomagnetic model that will propagate these long period waves when constrained by a more intense field.

V. THE S/C ROLL ORIENTATION DURING THE PERIOD $16^h33^m25.5^s$ DAY 333 THROUGH 07^h50^m DAY 334

The roll orientation of the S/C as a function of time was required at all times in order to properly interpret the magnetic field data in terms of models, etc. This is particularly true during the first few days after launch. A preliminary analysis of the S/C field and R.F. field strength data had been carried out to determine the roll orientation prior to canopus acquisition and the experimenters felt that a more comprehensive study of the problem

Fig. 8 - Preferred Period over 10 min Intervals from Rapid-Run Magnetograms versus Corresponding 10 min Averages of Magnetic Field at Probe



was necessary before the magnetic data analysis covering this period could be carried further. This subsequent analysis of the AGC data was carried out at BYU during the initial phase of our work here.

The analysis covered the period $16^h33^m25.5^s$ of day 333 through 07^h50^m of day 334. The effort was primarily directed at obtaining an equation for the roll orientation of the spacecraft as a function of time. Both autocorrelation and phase techniques were employed. The latter method of analysis was what was actually employed to obtain the resulting dependence of the roll angle on t, with the former being used primarily as a check to see if the changing cone angle of the tracking station caused a shift in the relative position of the feature used in the phase method.

<u>S/C Roll Before $06^h59^m03^s$.</u> The autocorrelation function $C(\tau)$ for blocks of data amounting to several roll periods were computed using standard techniques (i.e., Blackman and Tukey, etc.), and the lag τ corresponding to a peak in $C(\tau)$ that occurred in the vicinity of the roll period was determined for each data block. This value of τ was assumed to best approximate the pseudo roll period (referred to the tracking station) as the changing clock angle of the tracking station had not been removed. A comparison of these results with the dependence of the roll period on time as determined from the times of occurrence of a certain feature in the AGC pattern (again, uncorrected for the clock angle change of the spacecraft) appears to verify that there was no relative change of the feature used with respect to the general periodic variation in the AGC signal with changing cone angle of the tracking station. Plots of the period (τ) values and resulting least

squares straight line fits for both methods are shown in figure 9 and 10. Considering the scatter in the points, the agreement of the two methods is quite good.

Having established that any change in the relative position of the feature used in the phase method is probably small, the actual angles through which the spacecraft rotated during the time interval between the successive appearance of the AGC feature taking into account the changing clock angle of the tracking station were computed as well as the average values of θ for each time interval. A plot of $\dot{\theta}$ vs t referred to the mid-point of each time interval is shown in figure 11. The open circles refer to Woomera data, the filled circles to Johannesburg data. The scatter in the points is primarily due to the sampling interval and the necessity of estimating the time of occurrence of the feature. (The scatter from 0200 to 0400 of day 334 appears to have been caused by a clock error at the station. This is discussed later.) Whereas the scale used in the plot shows a fair degree of scatter, one notes that: (1) the Woomera and Johannesburg data appear to merge quite well, and (2) there is a clear suggestion of an assymptotic decrease in $\dot{\theta}$ with time, with an assymptotic value of ~ 0.2046 degrees/sec being suggested. This suggested a possible effect one might expect if one considers eddy currents produced by a rotating conductor in a magnetic field that is decreasing with time in a manner similar to that for the Mariner IV. Of course if the friction losses in gyros decreased with time, this could be an attractive mechanism. The former would probably generate a field in the direction of $\vec{\omega} \times \vec{B}$ which would not affect the offset values,

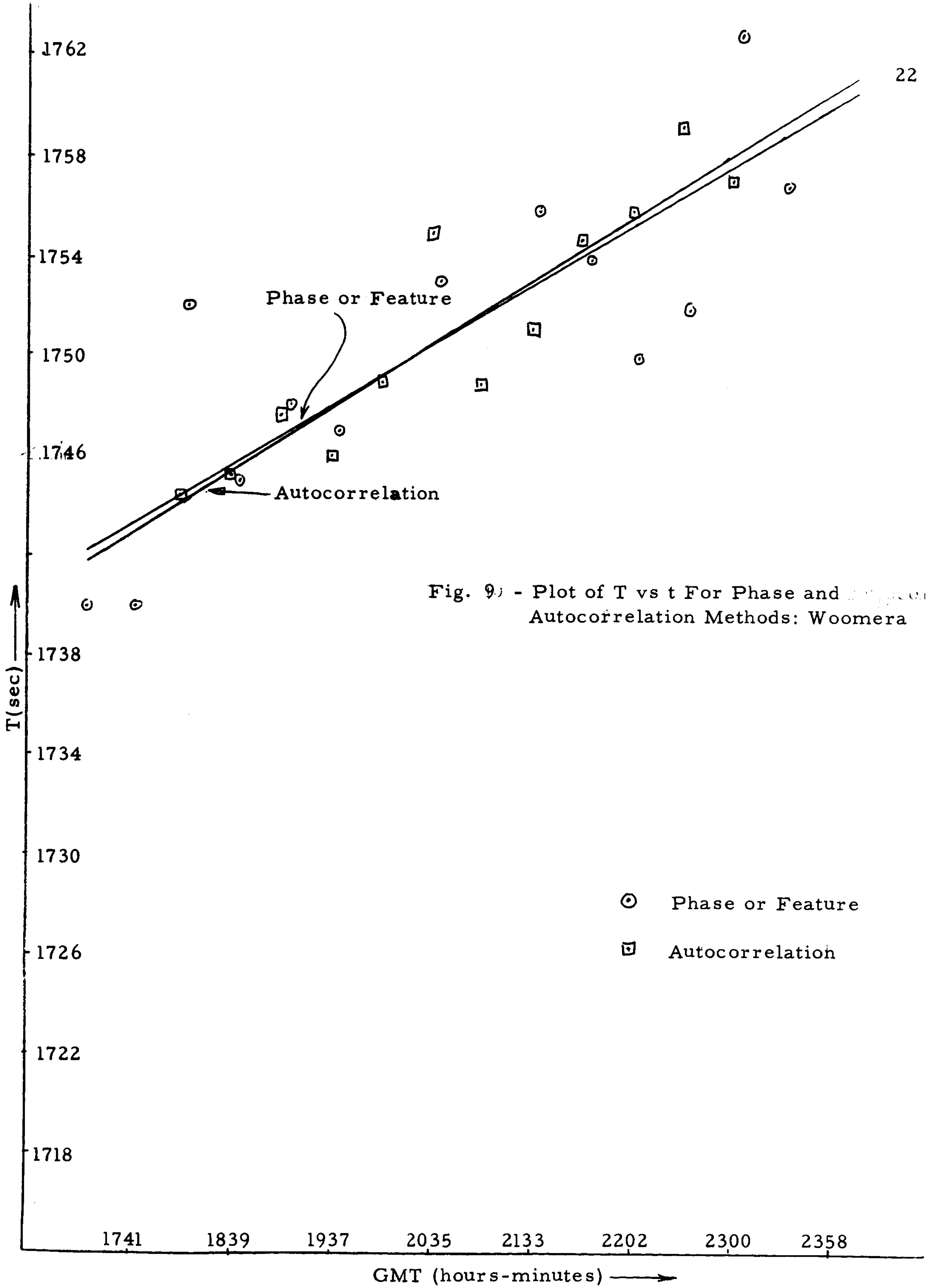


Fig. 9 - Plot of T vs t For Phase and
Autocorrelation Methods: Woomera

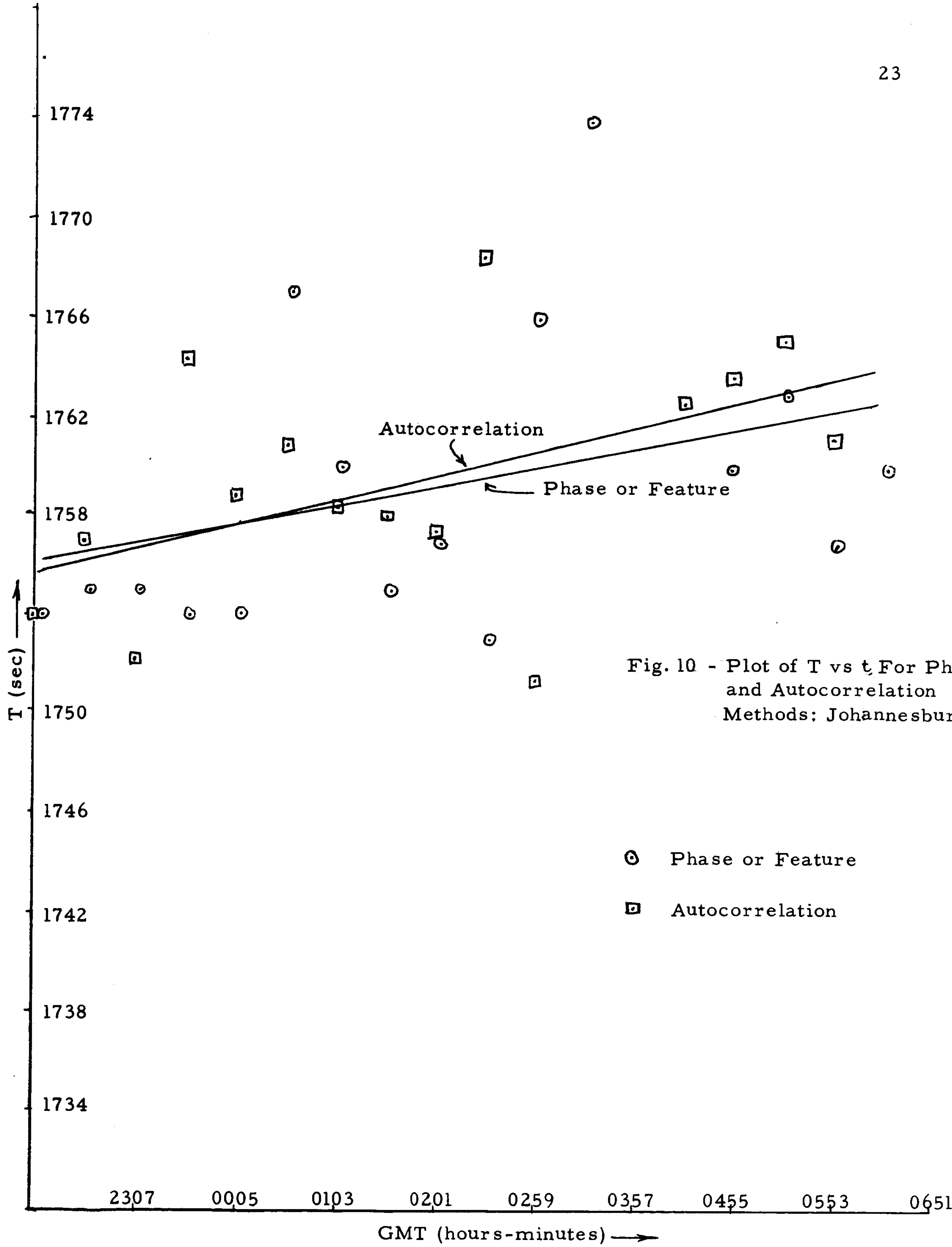


Fig. 10 - Plot of T vs t For Phase and Autocorrelation Methods: Johannesburg

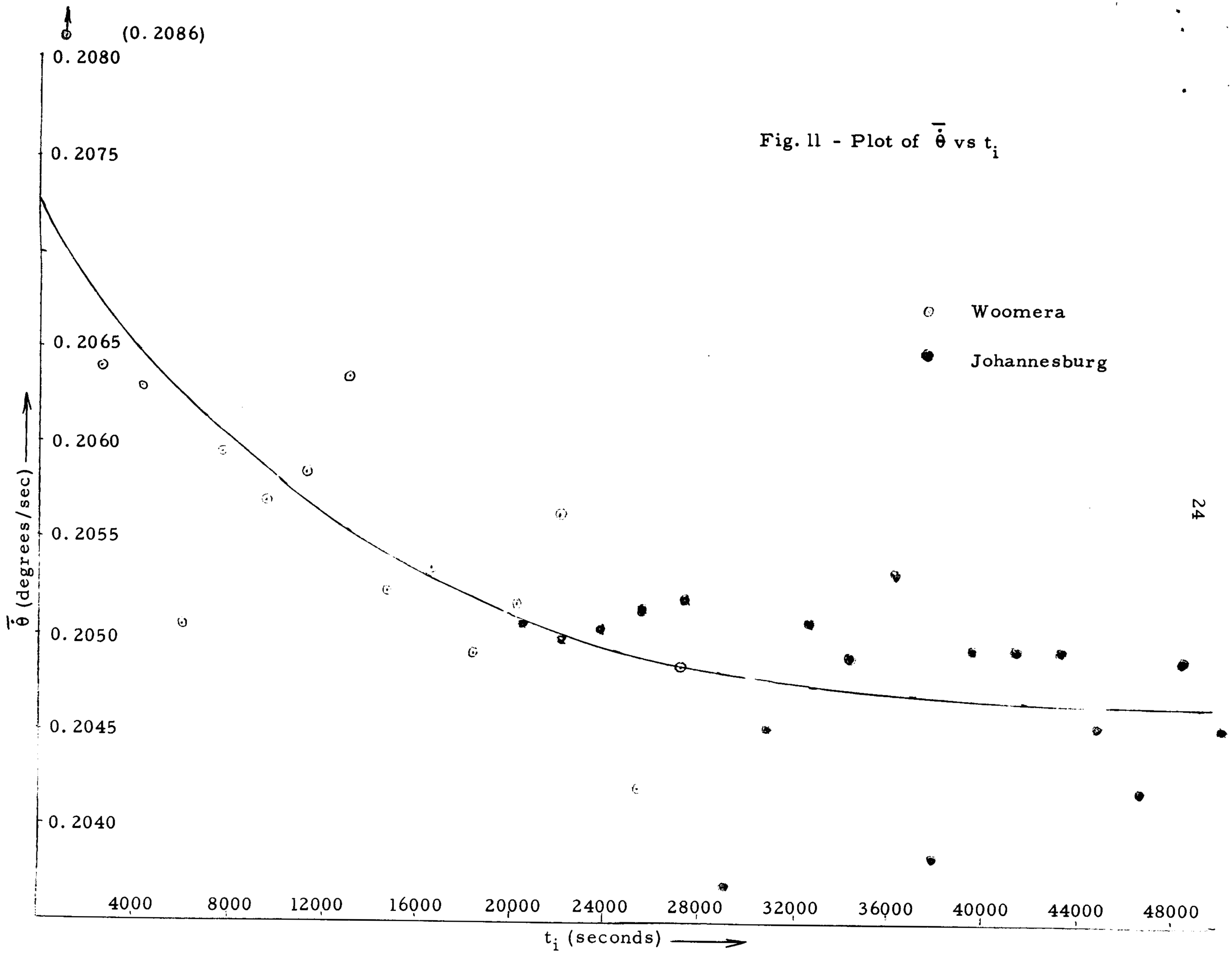


Fig. 11 - Plot of $\bar{\dot{\theta}}$ vs t_i

and affect the terrestrial field readings only slightly.

A four degree polynomial fit to the $\dot{\theta}$ vs t curve was computed from which the following 5 degree equation for θ vs t was obtained (referred to solar ecliptic coordinates) for the period $16^h33^m25.5^s$ Day 333 through $06^h59^m03^s$ Day 334:

$$\theta = 122.24 - 0.2072\, t_i + 0.9447 \times 10^{-7} t_i^2 - 1.7441 \times 10^{-12}\, t_i^3 + 1.6062 \times 10^{17} t_i^4$$
$$-0.5560 \times 10^{-22} t_i^5 \text{ degrees}$$

where $t_i = t - t_o$ (in seconds)

$$t_o = 16^h33^m25.5^s$$

The determination of the reference angle of 122.24° was based upon the assumption that the feature in the AGC pattern that was used during the Woomera run occurred precisely at the time that the S/C high gain antenna was pointed at the tracking station. A comparison of the above equation with the earlier results of Davis shows roughly a 4 to 5 degree constant difference between the two. This undoubtedly results because of the different criteria used for determining the reference angle θ.

A plot of the difference between the S/C angle predicted by the above equation and angle corresponding to the time of the feature in the AGC signature is shown plotted in figure 12. The probable error of the fit correspondings to about 0.7° in angle.

S/C Roll After $06^h59^m03^s$

Roll search was initiated at $06^h59^m03^s$ and the roll rate slowed to approximately 0.115 degrees/sec. This was determined by noting the times at which features of the AGC pattern appeared and consequently computing the average

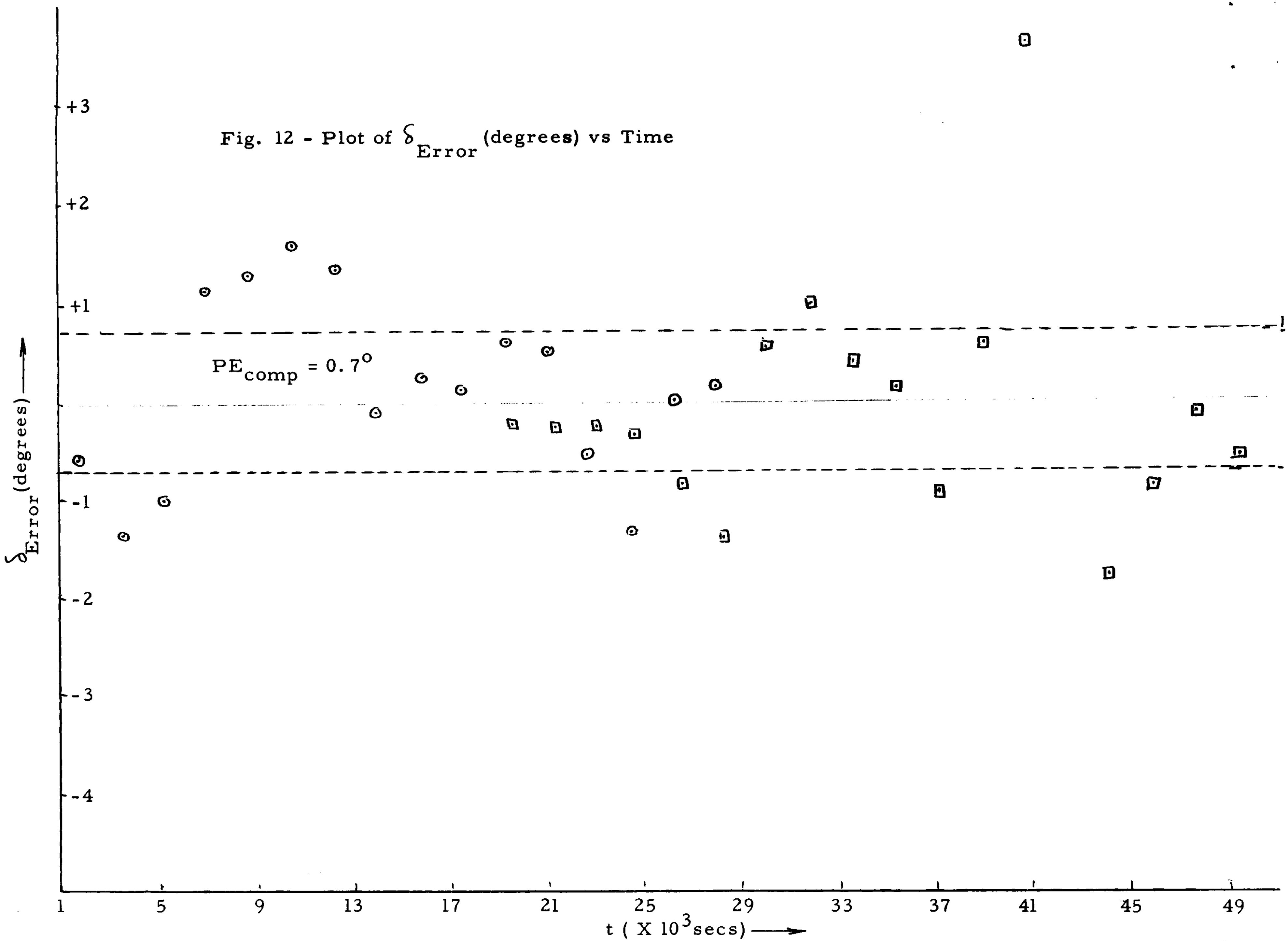


Fig. 12 - Plot of δ_{Error} (degrees) vs Time

change in the time scale. This roll rate persisted until about 07^h10^m. From about 07^h10^m there is a suggestion that the roll actually was stopped until about 07^h13^m. However, the attitude control people conclude that the normal time delay in the S/C logic initiated at $07^h07^m34^s$ caused the gyros to be turned off at $07^h10^m03^s$, at which time the S/C did not stop rolling.

The AGC pattern suggests that from $07^h10^m03^s$ until the S/N dropped so low it became useless (at about $07^h50^m00^s$) the roll rate was probably not constant. From $07^h10^m03^s$ to about $07^h28^m40^s$, the roll rate was 0.0091 degrees/sec (if the roll never was stopped) and from $07^h28^m40^s$ through about $07^h50^m00^s$ it was 0.0146 degrees/sec. The AGC data is very noisy here and consequently not much faith is placed on the latter number in particular, although it is doubtful it is too far off. One should note that if the S/C roll indeed was stopped from $07^h10^m03^s$ through $07^h13^m00^s$, then the roll rate from $07^h13^m00^s$ to $07^h28^m40^s$ was about 0.0105 degrees/sec.

At $07^h07^m34^s$ the attitude control people interpret signals received by the Canopus tracker (earth light?) that it was at a clock angle of 129 ± 3 degrees. At this time the tracker is computed to be at a clock angle of 129.03 degrees using the equations derived here.

Anomalous Behavior

In general the AGC data do not exhibit any anomalous behavior except for the period 0230 through $04^h01^m41^s$ day 334. This appears to have been due to an apparent malfunctioning of the clock at Johannesburg. Between $04^h01^m41^s$ and $04^h08^m41^s$ the clock was being recycled, and the data after that time appears to be normal. A plot of time shift Δt required for a best fit of 29 minute increments when superimposed on the next succeeding 29 minute increment is shown in figure 13. From $\sim 01^h00^m$ through 06^h59^m the roll rate is decreasing very slowly and the required increment shift Δt should be fairly constant. However, it is clear from figure 13 (i refers to the block number of the initial data block used in determining the value of Δt) shows an anomalous behavior from i = 10 through i = 14. The corresponding times are noted on the plot. This is in the general region where Davis also noted an anomaly (near his n = 210).

Several possible causes of this anomalous behavior were considered:

1. The roll rate actually changed, being a result of the sequential firing (after suitable time delay) of two pairs of roll jets, the net result being that the roll rate was not changed after the sequence was complete.
2. The antenna pattern being an abrupt function of the cone angle.
3. There was trouble with the clock (or print out of same) at Johannesburg which was subsequently corrected upon recycling etc.

Item 2 can be ruled out on a purely physical basis as such a functional dependence of the antenna pattern on the cone angle is out of the question. As to item 1, it is clear that the roll jets did not fire (at least they had no reason to). From figure 11 the roll rate is seen to decrease approximately exponentially from a value of 0.20724 to 0.2046 degrees/second over the period $16^h33^m25^s$ to $06^h50^m03^s$ corresponding to a change of 3.6171 to 3.5709 x 10^{-3} rad/sec. The S/C roll rate data channel indicated a DN value of 78 corresponding to 3.67 $\pm$ 0.13 x 10^3 rad/sec. The dead zone minimum value (assuming the $\sim$10% tolerance) was $\sim \pm$ 0.30. Since nominal was to be 3.55 x 10^{-3} rad/sec, this

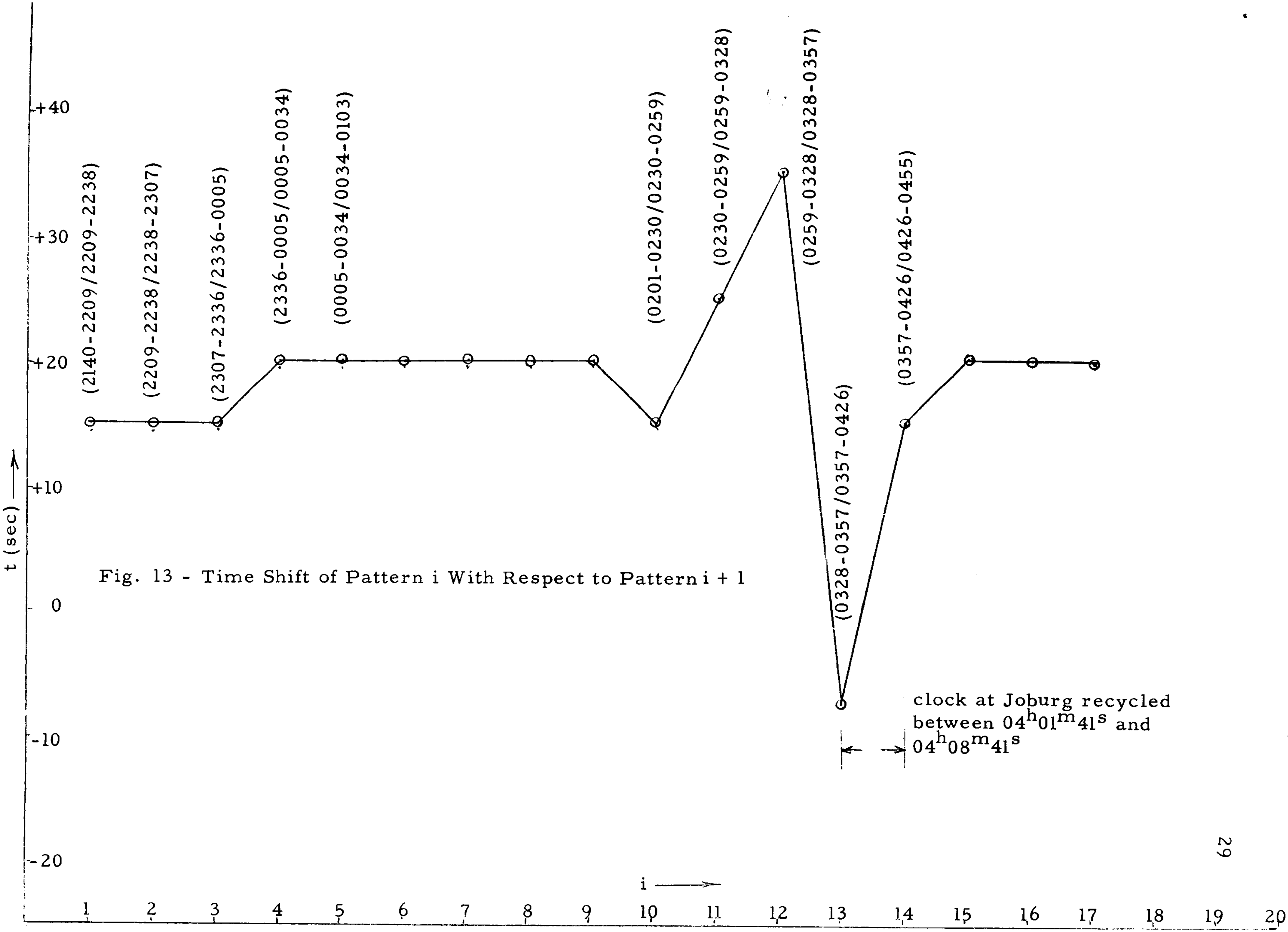


Fig. 13 - Time Shift of Pattern i With Respect to Pattern i + 1

meant that the roll jets should not have fired unless the roll rate was less than 3.20 or greater than 3.85×10^{-3} rad/sec. Clearly the computed roll rate limits over the time in question are; (1) compatible with the indicated DN value of 78 and (2) well within the minimum dead zone limits. From this information in combination with the fact that there was no clear cut evidence from the magnetometer data indicating field transient caused by the firing of the roll jets (this argument is somewhat weak), we must conclude that the jets did not fire. Hence, we conclude that the clock at Johannesburg was malfunctioning during this time.

VI. S/C FIELD DETERMINATION

Two methods have been used by us to estimate the magnitude of the X and Y components of the spacecraft field. In the first method, the field components were determined by locating the axis of the M_x or M_y vs t plots covering the time interval from FC 330 through 715 ($16^h 24^m 50^s$ through $17^h 47^m 47^s$ of Day 333). The results are

$$B_x = 2.5$$

$$B_y = 9.0$$

The X and Y values of the S/C offset are those corresponding to minimum values of s, where s is obtained from

$$s = \sqrt{\sum_{i=i}^{n} \frac{(\Delta t_i - \overline{\Delta t})^2}{n=1}}$$

where Δt_i is the i^{th} time interval between succeeding intersection of the M_x or M_y vs t plot and the assumed horizontal axis, and $\overline{\Delta t}$ is the sample average. It would be desirable to be able to relate a tolerance on the offset values listed above to the corresponding minimum values of s, but it is not clear how this can be done. Even if there was no "noise" in the data, the value of s would obviously not be zero.

The second method utilized the field measurements obtained during the period after the S/C had clearly passed the magnetosphere boundary. In this method, the roll equations were used to transform the field readings into the solar equatorial coordinate system and the power spectra of the resulting data computed. The X and Y offset values were varied until the relative power at the roll frequency was a minimum. Any offset component that has not been removed will result in some power being obtained at the roll frequency that is greater than that expected based upon the power at nearby frequencies caused by noise or true variations in the ambient field. This method resulted in the following values for "gyros" on condition:

$$B_x = 1.6\gamma$$

$$B_y = 11.4\gamma$$

These are to be compared to the "May" values being used of 1.8γ and 11.0γ respectively.

It is apparent that the results of the two methods do not agree as well as would be expected, particularly in the case of the Y components. This suggests the possibilities that the offset values were changing with time and we attempted to pursue this possibility by computing the required offset values for minimizing the power at the roll frequency for three blocks of data. There was some suggested change in the minimizing offset values, and these were showing a trend in the correct direction. However, power spectra are very expensive and we have since given this aspect of the problem a low priority. If real, the change was probably of an asymptotic nature, and the values obtained from the "Neutral field" data noted by Coleman[14] tends to back this up ($Bx \simeq 2.1\gamma$, $By \simeq 10.7\gamma$).

VII. REFERENCES

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